Fishery Data Series No. 09-01

Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2005

by

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and

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February 2009

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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February 2009

This investigation was partially financed by the U.S./Canada Salmon Research Cooperative under NOAA Cooperative Agreement Award Number NA04NMF4380264.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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This document should be cited as:
Dunbar, R. D., and C. T. Pfisterer. 2009. Sonar estimation of fall chum salmon abundance in the Sheenjek River, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 09-01, Anchorage.

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ABSTRACT

Dual-Frequency Identification Sonar (DIDSON) was used to estimate chum salmon, (*Oncorhynchus keta*) escapement in the Sheenjek River from August 10 to September 24, 2005. This was the first season that DIDSON was used to estimate chum salmon passage in the Sheenjek River, and the first season that both banks were fully monitored since 1987. The sonar-estimated escapement was 438,253 chum salmon through September 24. The estimate was subsequently expanded to a total abundance estimate of 561,863 using run time data from the Rampart tag recovery fish wheel. For comparison with past years, only the expanded right bank estimate of 365,701 was used to evaluate whether the biological escapement goal (BEG) was obtained. Median passage while the sonar was operating was observed on September 9. Peak single day passage was September 11, when an estimated 26,150 fish passed the sonar site. The diel migration pattern as seen in past seasons was not as pronounced in 2005. Range of ensonification was considered adequate for most fish which passed. The passage estimate should be considered conservative since it does not include fish migrating beyond the counting ranges, and fish present before sonar equipment was in operation. Two hundred three vertebrae samples were collected for age determination. Analysis of vertebrae collections showed age-4 fish dominated at 92.3%, age-5 fish represented 6.7%, and age-6 about 1% of all fish sampled. No age-3 fish were captured. Male chum salmon comprised 54% of the sample and 46% were female.

Hydroacoustic Technology Inc. (HTI) split beam sonar, previously operated at this site, was operated side by side with the new DIDSON on the right bank from August 18 through September 11, 2005. Analyses of data collected this season suggest that the DIDSON estimates were 20% higher than the split-beam estimates.

Key words: chum salmon, *Oncorhynchus keta,* sonar, hydroacoustics, escapement, enumeration, Yukon River, Porcupine River, Sheenjek River

INTRODUCTION

Five species of anadromous Pacific salmon *Oncorhynchus* are found in the Yukon River drainage. However, chum salmon *O. keta* are the most abundant and occur in genetically distinct summer and fall runs (Seeb et al. 1995; Wilmot et al. 1992). Fall chum salmon are larger, spawn later, and are less abundant than summer chum salmon. Spawning occurs in upper portions of the drainage in spring-fed streams, which usually remain ice-free during the winter (Buklis and Barton 1984). Major fall chum salmon spawning areas occur within the Tanana, Chandalar, and Porcupine River systems, as well as portions of the upper Yukon River in Canada (Figure 1). The Sheenjek River (66° 47.02 N 144° 27.82 W) is one of the most important producers of fall chum salmon in the Yukon River drainage. Located above the Arctic Circle, it heads in glacial ice fields of the Romanzof Mountains, a northern extension of the Brooks Range, and flows southward approximately 400 km to its terminus on the Porcupine River (Figure 2).

INRIVER FISHERIES

Fall chum salmon are harvested for commercial and subsistence uses. Commercial harvest is permitted along the entire Yukon River in Alaska and in the lower portion of the Tanana River. No commercial harvest is permitted in any other tributaries of the drainage including the Koyukuk and Porcupine River systems. Although commercial harvest occurs in the Canadian portion of the Yukon River near Dawson, most fish are taken commercially in the lower river, downstream of the village of Anvik. Subsistence use of fall chum salmon is greatest throughout the upper river drainage, upstream of the village of Koyukuk.

Although the Alaskan commercial fishery for Yukon River fall chum salmon developed in the early 1960s, annual harvests remained relatively low through the early to mid 1970s. Estimated total inriver utilization (U.S. and Canada commercial and subsistence) of Yukon River fall chum salmon was below 300,000 fish per year before the mid 1970s (JTC 2006). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s. Harvest peaked in 1981 at 677,257 fish (Appendix A1). In the mid 1980s, management strategies were implemented to reduce commercial exploitation on fall chum stocks and to improve low escapements observed throughout the drainage during the early 1980s. In 1987, the commercial fall chum fishery was completely closed in the Alaskan portion of the drainage. In 1992, commercial fishing was restricted to a portion of the Tanana River during the fall season. In addition to a commercial fishery closure, 1993 marked the first year in state history that Alaska Department of Fish and Game (ADF&G) instituted a total closure of subsistence fishing in the Yukon River. The closure was in effect during the latter portion of the fall season in response to the extremely weak fall chum salmon run.

Yukon River fall chum salmon runs improved somewhat from 1994 through 1996. In 1994, limited commercial fishing was permitted in the Alaskan portion of the upper Yukon River, and in the Tanana River. Commercial fishing was permitted in all districts throughout the Alaska portion of the drainage in 1995. In 1996, limited commercial fishing was only permitted in selected districts of the mainstem Yukon River and no commercial fishing was permitted in the Tanana River. Poor salmon runs to Western Alaska from 1997 to 2003 resulted in partial or total closures to commercial and subsistence fishing in Alaskan and Canadian portions of the drainage. Commercial fishing was only permitted in the Tanana River and Canada in 1997. A total commercial fishery closure and limited subsistence fishing was required in 1998. Limited commercial harvest was permitted in 1999, and a total commercial fishery closure and severe subsistence fishing restrictions were required in 2000, 2001, and 2002. Limited commercial fishing for fall chum was allowed in 2003, 2004, and 2005. Subsistence harvest of fall chum in 2003 was also limited while the subsistence harvest in 2004 was unrestricted except within the Canadian portion of the Porcupine River. There were no restrictions on subsistence harvest in 2005.

ESCAPEMENT ASSESSMENT

During the period of 1960 through 1980, only some segments of Yukon River fall chum salmon runs were estimated from mark–recapture studies (Buklis and Barton 1984). Excluding these tagging studies, and apart from aerial assessment of selected tributaries since the early 1970s, comprehensive escapement estimation studies were sporadic and limited to only 2 streams: the Delta River (Tanana River drainage) and the Fishing Branch River (Porcupine River drainage). In the early 1980s, comprehensive escapement assessment studies intensified on major spawning tributaries throughout the drainage.

The Sheenjek River is one of the most intensely monitored fall chum salmon spawning streams in Yukon River drainage. Escapement observations date back to 1960 when U.S. Fish and Wildlife Services (USFWS) reported chum salmon spawning in September. From 1974 to 1981, escapement observations in the Sheenjek River were limited to aerial surveys flown in late September and early October (Barton 1984). Subsequent to 1980, escapements were monitored annually using fixed location, single beam, side looking sonar systems (Dunbar 2004). However, an early segment of the fall chum salmon run was not included by sonar counting operations from 1981 through 1990 because late project startups centered around August 25. By comparison, the average startup during the 1991 through 2004 period was August 8, more than 2 weeks earlier than previous years. The sonar-estimated escapements for the years 1986 through 1990 were subsequently expanded to include fish passing before sonar operations began (Barton 1995). Termination of sonar counting was consistent during the period 1981 through 2005, averaging September 24, except in 2000 when the project was terminated early because of extremely low water (Barton 2002).

The Sheenjek River sonar project has estimated fall chum salmon escapement since 1981 and has undergone a number of changes in recent years. The project originally operated Bendix[1] single-beam sonar equipment and, although the Bendix sonar functioned well, the manufacturer ceased production in the mid 1990s and no longer supports the system. In 2000, ADF&G purchased a Hydroacoustic Technology, Incorporated (HTI) model 241 split-beam digital echosounder for use on the Sheenjek River. In 2000 and 2002 the new split-beam system was deployed alongside the existing single-beam sonar and produced results comparable to the Bendix equipment (Dunbar 2004). In 2003 and 2004 the split-beam sonar system was used exclusively to enumerate chum salmon in the Sheenjek River.

Annual escapement estimates averaged 100,533 spawners for the period 1991–2000 and approximately 39,517 spawners for the most recent 5 year period of 2000–2004 (Table 1). From 1992 through 2000 the Sheenjek River minimum biological escapement goal (BEG) was 64,000 fall chum salmon, based upon 1974 to 1990 aerial indices and hydroacoustic assessment (Buklis 1993). In 2001, the department completed a review of the escapement goal for Yukon River fall chum stocks of which the Sheenjek River assessment is a component. Based on this review of long term escapement, catch, and age composition data, the BEG for the Sheenjek River was set at a range of 50,000 to 104,000 fall chum salmon (Eggers 2001).

STUDY AREA

The sonar project site is located approximately 10 km upstream from the mouth of the Sheenjek River. Although created by glaciers, the Sheenjek River has numerous clearwater tributaries. Water clarity in the lower river is somewhat unpredictable, but is generally clearest during periods of low water. The water level normally begins to drop in late August and September. Upwelling ground water composes a significant proportion of the river flow volume, especially in winter. It is in these spring areas that fall chum salmon spawn, particularly within the lower 160 km.

Historically, because of unfavorable conditions for transducer placement on the left bank[2], only the right bank of the Sheenjek River has been used to estimate fish passage, except for 1985 through 1987 when single-beam sonar was tested on the left bank. Drift gillnet studies in the early 1980s suggested that distribution of the upstream migrant chum salmon was primarily concentrated on the right bank of the river at the current sonar site, with only a small but unknown proportion passing on the left bank (Barton 1985). In 2002, ADF&G began testing a new Dual Frequency Identification Sonar (DIDSON) for counting salmon in small rivers. Based on the results of these tests, which showed this equipment to be easier to use, more accurate, and capable of operating with substrate profiles that are unacceptable for split-beam systems (Maxwell and Gove 2004), the Sheenjek River was selected as an ideal candidate for this system. In an effort to estimate the proportion of fish passing on the left bank, a DIDSON was deployed there in 2003. Results indicated that approximately 33% of the fish were migrating up the left bank (Dunbar 2006). Due in part to the large number of fish observed on the left bank, ADF&G proposed operating DIDSON on both banks in the future. In 2004, the DIDSON was tested side-by-side with the split-beam sonar on the right bank to examine differences in the estimates produced by the 2 types of sonar and whether escapement goals will need to be reevaluated. In 2005, DIDSON was operated on both banks to estimate chum salmon escapement in the

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[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.
[2] Left and right bank refers to the bank on the left or right side of the river when looking downstream.

Sheenjek River. The HTI split-beam sonar was also operated side-by-side with the DIDSON on the right bank for further comparison.

OBJECTIVES

Goals for the 2005 Sheenjek River fall chum salmon study were to estimate the timing and magnitude of adult salmon escapement, characterize age and sex composition, and to deploy, test, and compare chum salmon passage estimates of the new DIDSON to those of the split-beam sonar system. To accomplish this, these specific objectives were identified:

1. Estimate daily and seasonal passage of chum salmon escapement using fixed-location, DIDSON, side looking hydroacoustic techniques.
2. Collect a minimum of 30–35 vertebrae samples per week, up to 180 for the season, to estimate age and sex composition of the spawning chum salmon population, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 (α=0.05 and d=0.10).
3. Collect selected climate and hydrologic parameters daily at the project site for use as baseline data.
4. Deploy and operate HTI split-beam sonar side-by-side with the DIDSON system on the right bank, and compare the split-beam passage estimates with the DIDSON.

METHODS

HYDROACOUSTIC EQUIPMENT

Two DIDSON units manufactured by Sound Metrics Corporation were deployed on the right and left banks of the Sheenjek River at the historic sonar site to monitor fish passage (Figures 3 and 4). The right bank DIDSON (long range) was operated at 1.2 MHz, its high frequency option, using 48 beams, and the left bank DIDSON (standard) was operated at 1.1 MHz, its low frequency option, using 48 beams. Both the low and high frequency modes have a viewing angle of 29° by 14°. Both DIDSON units were attached to HTI model 662H dual-axis rotators, using HTI model 660 remote controllers to facilitate aiming. A 152 m cable carried power and data between the DIDSON units in the water and the topside breakout boxes. A wireless router transferred data between the left bank breakout box and a laptop computer on the right bank. All surface electronics were housed in a small self-supporting tent on the left bank and a 10x12 wall tent on the right bank. Hydroacoustic equipment and computers were powered with portable 1000 W generators that ran continuously. Sampling was controlled by DIDSON software installed on laptop computers. After all parameters were determined for data acquisition, both left and right bank systems operated 24 hours a day. Passage data was collected in forty-eight 30 minute digital text file samples per bank and day by the DIDSON data acquisition software. Files were later examined and edited by the field crew to produce an estimate of fish passage. The crew, consisting of 3 technicians, monitored the sonar and interpreted the data during three 6 to 7 hour shifts per day.

SITE SELECTION AND TRANSDUCER DEPLOYMENT

The gently-sloping river bottom and small cobble at the historic right bank counting location, and the cut bank directly across the river, proved adequate for ensonification. A detailed bottom profile was obtained after initial transducer placement at the counting location by stretching a rope across the river and measuring water depth at one meter increments with a calibrated pole.

The transducers and automatic rotators were mounted on pods made of aluminum pipe and deployed from each bank. The pods were designed to permit raising and lowering of the transducers by sliding them up or down along 2 riser pipes that extended above the water and were secured in place with sandbags. Fine adjustments were made with remote control of the dual-axis rotators attached to the transducer. The transducers were deployed in water ranging from approximately 0.5 m to 1.0 m in depth, and aimed perpendicular to the current along the natural substrate. An attempt was made to ensure the transducers were deployed at locations where minimum surface water velocities did not fall below 30 cm/s.

The system operators used an artificial acoustic target during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beams. The target, an airtight 250 ml weighted plastic bottle, was allowed to drift downstream along the river bottom and through the acoustic beams. Several drifts were made with the target in an attempt to pass it through as much of the counting range as possible. Proper transducer aim was verified with visual interpretation (echogram) on a computer screen.

As in previous years, a fish lead was constructed shoreward from the transducer on the right bank to prevent upstream salmon passage inshore of the transducer. The fish lead was constructed using 5 cm by 5 cm by 1.2 m high galvanized chain-link fencing and 2.5 m metal "T" stakes. The lead was positioned to include the nearfield of the sonar transducer. Whenever the transducer was relocated because of rising or falling water level, the lead was moved inshore or offshore as appropriate, and the artificial target used to ensure proper re-aiming. No fish lead was installed on the left bank because of the deep water and floating debris close to shore. Because of the deep water at the cut bank, the transducer was placed very close to shore, and natural diversions such as submerged debris and fallen clumps of riverbank were exploited to keep salmon from passing behind or to close to the transducer.

SONAR COUNT ADJUSTMENTS

During each work shift, digital data collected by the DIDSON from both banks was transferred to another computer for counting and editing using DIDSON editing software. Upstream migrating fish were counted by marking each fish track on the DIDSON echogram. Figure 5 shows an example of a DIDSON echogram. Upstream direction of travel was verified using the DIDSON video feature. Counts were saved as text files and recorded on a count form. Hourly estimates were exported to a *Microsoft Excel* spreadsheet where they were adjusted with linear interpolation or expansion for periods when data collection was interrupted. Brief interruptions intermittently occurred when routine maintenance (i.e. silt removal) or relocation of the transducers were required. When a portion of an hourly sample was missing, passage was estimated based on the fraction of the hour that was sampled. The number of minutes in a complete sample was divided by the known number of minutes counted and then multiplied by the number of fish counted in that period. If data from one or more complete hourly samples was missing, counts were interpolated by averaging counts from samples before and after the missing sample(s). Sonar counts caused by fish other than salmon were assumed insignificant based upon historic visual “tower” observations and test fishing records collected at the site. After editing was complete, an estimate of daily and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone. The estimates produced during the field season were further scrutinized postseason, and adjusted as necessary.

TEMPORAL AND SPATIAL DISTRIBUTIONS

Fish range distributions were examined postseason by importing text files containing all fish track information into an *R* statistical software package (R Development Core Team 2004). Range histograms were produced in Microsoft® *Excel* to investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were also created in Microsoft® *Excel* to investigate diel patterns of migration.

TEST FISHING AND SALMON SAMPLING

Region-wide standards have been set for the sample size needed to describe the age composition of a salmon population. These standards apply to the period or stratum in which the sample is collected. Sample size goals are based on a one in ten chance (precision) of not having the true age proportion (p_i) within the interval $p_i \pm 0.05$ for all *i* ages (accuracy).

The preferred method of aging Yukon River fall chum salmon, when in close proximity to their natal streams, is from vertebrae collections (Clark 1986[3]). As described in Bromaghin (1993), a sample size of 150 chum salmon is needed, assuming 2 major age classes with minor ages pooled, and no unreadable vertebrae. Allowing for 20% unreadable vertebrae, the Sheenjek River sample size goal was to sample approximately 30 chum salmon per week up to a maximum of 180.

An adult salmon beach seine was periodically fished at different locations between the sonar site and approximately 8 km upstream to collect adult salmon for age and sex composition. The beach seine (3 in stretch measure) was 30 m in length by 55 meshes deep (~3 m). Chum salmon were collected with the beach seine, enumerated by sex using external characteristics, and measured to the nearest 5 mm, from mid eye to tail fork (METF). Additionally, 3 vertebrae were taken from each fish for age determination.

CLIMATE AND HYDROLOGIC OBSERVATIONS

A water level gauge was installed at the sonar site and monitored daily, with readings made to the nearest centimeter. Surface water temperature was measured daily with a pocket thermometer. Minimum and maximum air temperatures, and wind velocity and direction were measured daily with a Weather Wizard III weather station. Other daily observations included recording occurrence of precipitation and estimating percent cloud cover. Climate and hydrologic observations were recorded at approximately 1800 hours daily.

SPLIT-BEAM AND DIDSON COMPARISON

To understand the relationship between the DIDSON estimates and estimates produced by split beam sonar, HTI fixed-location, split-beam sonar was operated side-by-side with the DIDSON on the right bank of the Sheenjek River. The split-beam sonar was deployed using the same type of pod as the DIDSON. Attached to the transducer was an HTI model 662H dual-axis rotator with HTI model 660 remote controller to facilitate aiming. The electronic equipment was kept in the same tent as the DIDSON equipment and powered with the same 1000 watt generator. The split-beam sonar was set to ensonify the same range as the DIDSON. The split-beam sonar was usually operated for a 48-h period, then skipping a day, and then operated again for another 48-h

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[3] Clark, R. A. 1986. Sources of variability in three ageing structures for Yukon River fall chum salmon (*Oncorhynchus keta* Walbaum) escapement samples. Alaska Department of Fish and Game, Division of Sport Fish, (Region III unpublished report), Fairbanks.

period. The split-beam was not operated every day due to the time and cost associated with additional operating and processing.

Fish passage estimates were calculated using the two 30 minute samples collected during each hour of operation. Only hours with 60 minutes of data were used for comparison with the DIDSON system. The system operator manually counted the fish using electronic echograms, with DIDSON editing software used for the DIDSON estimate (Figure 5) and *Polaris* (Dunbar 2006) for the split-beam sonar estimate (Figure 6). Since any potential adjustments to historical estimates require a functional relationship between daily counts (historical hourly counts are not available), pairs of counts were grouped into 24-h groupings representing a complete day. A bootstrap approach was used since there were only 11 complete days of usable paired data. Daily groupings were obtained by randomly sampling 24 values from the paired data (with replacement) and repeating the process 5,000 times. Standard linear regression techniques were then employed using the DIDSON counts as the dependent variable.

RESULTS

RIVER AND SONAR COUNTING CONDITIONS

In 2005, the right bank transducer deployment approximated the same location on the point bar that was used in recent years, while the cutbank directly across the river worked well for the other transducer. On August 9 the river bottom at the counting location sloped gently from the convex bank (right-bank, point bar) at a rate of approximately 11 cm/m (bottom slope ≈ 6.4°) to the thalweg that lay approximately two-thirds of the way across the channel, and then rose abruptly (41cm/m, bottom slope ≈ 22.4°) toward the left bank (Figure 7). River width measured 43 m, and much of the nearshore zone along the concave, left cutbank, was cluttered with fallen trees and other woody vegetation.

The water level remained relatively low at the project site throughout 2005, with the lowest level recorded on August 27 (Figure 8, Appendix B1). With respect to the initial reading of the water gauge upon deployment on August 8, the water level changed very little up to August 28, when it then began to steadily increase to 62 cm above the initial level by September 13. Final measurement on September 24 was 36.0 cm above the initial level. Water temperature at the project site ranged from 6.0°C to 17.0°C based upon instantaneous surface measurements, and averaged 9.8°C (Figure 8, Appendix B1).

Fluctuations in water level affected placement of the transducers with respect to shore, and in turn the proportion of the river ensonified. With installation of sonar on both banks, and the low water levels, efforts were made to insure that the counting ranges of each DIDSON did not overlap. While no attempt was made to estimate fish passage beyond the counting range, occasional expansions or interpolations of sonar counts were made to estimate fish passage for periods when data was missing because of system failures or moving the transducers.

ABUNDANCE ESTIMATION

The 2005 sonar-estimated escapement was 438,253 fall chum salmon for the 46-day period August 10 through September 24 (Table 2). Fish were counted from the data files during each shift, and adjustments to the equipment or data was made if necessary. Table 3 shows the amount of time by day that either expansion or interpolation was used to calculate hourly or daily passage estimates. Daily and cumulative passage estimates were relayed to the fishery managers in Fairbanks every morning via satellite telephone.

When the sonar operations ceased there was high (10,500 fish per day) and increasing passage, projects downriver experienced passage of large numbers of fish that would not have reached the sonar site by the time the project terminated, and many salmon were visually observed in the Sheenjek and Porcupine rivers when boating back to Circle. Given these circumstances, the sonar-estimated escapement was expanded to 561,863 to account for chum salmon that were most likely missed after termination of the project (Table 1) (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). The expansion was calculated by lagging the Sheenjek passage to correlate (best fit) with the Rampart tag recovery fishwheel daily catch per unit of effort (CPUE). The lag time was determined by lining up pulses of daily chum salmon CPUE at the fishwheel, and chum salmon counted at the sonar. It was determined that it took 6 days for the chum salmon to migrate from the Rampart tag recovery fishwheel to the Sheenjek sonar site. According to the fishwheel, only 78% of the chum salmon run had passed the Sheenjek sonar site when sonar operations ceased. The resulting equation for determining the season total chum salmon passage was:

$$y = x / 0.78 \qquad (1)$$

Where y is the season total chum salmon passage estimate after expansion and x is the sonar estimate on final day of counts.

TEMPORAL AND SPATIAL DISTRIBUTION

Chum salmon were present in the river when right bank sonar counting was initiated on August 10, as evidenced by the 447 fish estimated passing that day. Left bank sonar operation began on August 11. The largest passage estimate of 26,150 fish occurred on September 11(Figure 9). The interquartile portion of the run was observed from September 4 through September 14, with the median day of passage occurring on September 6. The average passage rate during the interquartile portion of the run approximated 21,431 fish per day. An estimated 10,559 chum salmon passed the project site on September 24, the final day of sonar operation. Only one distinct pulse of chum salmon passed the sonar site while it was operating, although it did appear that another pulse was developing when sonar operations were terminated.

The diel pattern of migration of Sheenjek River chum salmon typically observed on the right bank in most years (Dunbar 2004) was not as prevalent in 2005 (Figure 10). Overall there did not appear to be much diel fluctuations at the project site during the fall chum salmon run, although each side of the river showed a slight opposing diel fluctuation. The period of least movement in 2005 was 1200 hours, while the highest average passage occurred at 1500 hours.

During the fall chum salmon run, 61% of the salmon migrated on the right bank and 39% on the left bank. At the beginning of the season, the majority of the fish were migrating on the left bank, and then as the season progressed the majority of the fish passed on the right bank (Figure 11). Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. On the right bank approximately 96% of the fish counted were passing through the first 12 m of the counting range (Figure 12). The first few meters had fewer fish due to the placement of the fish lead in relation to the transducer. On the left bank, 92% of the fish were detected within 7 m of the transducer. The unusual range distribution on the left bank, as seen in Figure 12, was caused by natural diversions such as submerged debris (bush at 5–6 m) and fallen clumps of riverbank.

AGE AND SEX COMPOSITION

In 2005, a total of 203 chum salmon (109 males; 94 females) were captured for sampling (Table 4). Forty two seine hauls were made during the period of August 19 through September 23 along gravel bars between river kilometers (rkm) 10 and 18. Nine of the 203 vertebrae samples collected were unreadable. From the remaining 194 samples it was determined that age-4 predominated (92.3%), the proportion of age-5 fish observed was 6.7%, age-6 fish was 1.0%, and no age-3 fish were captured (Bales 2007) (Appendix C1).

SPLIT-BEAM AND DIDSON COMPARISON

Comparison of the DIDSON and split-beam sonar estimates was conducted during periods of moderately low and high passage during the period August 18 to September 11. During this 25-day period, 372 complete paired 1-hour samples were collected. Post season it was determined that the ping rate on the split-beam system was set slower than would be optimum for all fish velocities. Data collected after September 5 was not usable because of the slow ping rate, and increased fish velocities. Data collected up to that point (264-paired hourly samples) appeared to be acceptable, and included both moderately low and high passage rates. Daily right bank passage from August 18 through September 5 ranged from 831 to 13,620 chum salmon. From the data collected August 18 to September 5, the functional relationship (Figure 13) between the grouped split-beam and DIDSON counts was significant ($p < 0.001$) and had a high coefficient of determination ($r^2 = 0.9811$). The resulting linear equation was:

$$y = 1.20x + 43.56 \tag{2}$$

Where y is the grouped 24-hour DIDSON counts and x is the grouped 24-hour split beam counts.

DISCUSSION

ESCAPEMENT ESTIMATE

This was the first season that DIDSON was used to estimate fall chum salmon passage in the Sheenjek River, and the first season since 1987 that both banks were fully monitored. The DIDSON systems performed well on both right and left banks over the entire season with no major technical difficulties or failures. The DIDSON, with its wide beam angle (29°) was the ideal system for the previously unmonitored left bank, where the profile is steep and less linear than the right bank. Processing procedures for counting both DIDSON and split-beam files worked well for estimating salmon passage at the site. Most data files were easily processed in a reasonable amount of time.

Although sonar has been used to monitor chum salmon escapements in the Sheenjek River since 1981, project operational dates have only been consistent since 1991. Barton (1995) used run timing data collected from the nearby Chandalar River to expand Sheenjek River run size estimates for the years 1986–1988, and 1990 to a comparable time period. The 1989 estimate was expanded from aerial survey observations made before sonar operations in that year (Table 1). Barton (2002) used historic run timing data from 1986 to 1999 to expand the estimated escapement for 2000, when sonar operations terminated early. Because of unusually high and increasing passage when the project terminated in 2003, the sonar estimated escapement may not have reflected the actual amount of salmon escapement to the Sheenjek River. In order to assess whether the BEG was achieved, the escapement estimate was subsequently expanded using run timing data from the Rampart tag recovery fish wheel (Dunbar 2006, unpublished memorandum from Bonnie Borba, ADF&G, 24 February 2004). The same scenario occurred in 2005 - with high and increasing passage when operations ceased, and late run timing at other projects downriver, the escapement estimate was again expanded using run timing data from the Rampart tag recovery fish wheel (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). Visual evidence of many chum salmon still in the Sheenjek and Porcupine rivers also prompted expansion of the sonar estimate. Factors affecting termination of sonar counting in 2005 included logistics associated with closing down camp, and impending winter weather.

The 2005 sonar estimated escapement of 438,253 chum salmon, for the 46-day period from August 10 through September 24, was expanded to 561,863 to account for chum salmon that may have passed after sonar operations ceased (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). This escapement estimate was the largest ever recorded at the Sheenjek River, well above the BEG of 50,000 to 104,000 chum salmon (Table 1, and Figure 14). Even if only the right bank estimate of 266,962 (subsequently expanded to 337,927) is used, as was the case before this season, the estimate is well above the BEG. This large run was not expected because the major parent year escapement levels were 30,084 in 2000 (returning age-5 fish) and 53,932 in 2001 (returning age-4 fish).

Besides the extraordinary number of salmon that migrated past the sonar site in 2005, it was also interesting that 39% of the passage was on the previously unmonitored left bank. As mentioned in the introduction, it was believed that, based on drift gillnet studies conducted in the 1980s, a small but unknown proportion of the salmon pass on the left bank (Barton 1985). In 2003, a very short study using the DIDSON on both banks at the sonar site showed 33% of the fish migrated on the left bank (Dunbar 2006). Continued estimation of salmon passage on both banks will yield more accurate information on the total escapement to the Sheenjek River.

High numbers of returning fall chum salmon were also reported in the Chandalar River, where 496,484 chum salmon were estimated to have migrated past the sonar station during the 50 day period of August 8 through September 26 (Melegari and Osborne 2007). This was the largest estimate ever recorded on the Chandalar River. During the 58-day period of August 20 through October 16, 118,690 (subsequently expanded to 121,413) chum salmon passed the DFO weir on Fishing Branch River (JTC 2006). The 2005 Fishing Branch River escapement was slightly above the interim escapement goal range of 50,000 to 120,000 chum salmon.

The 2005 season was characterized by above average odd-year fall chum salmon runs to most Yukon drainage river systems. All fall chum salmon escapement goals were achieved within the Yukon River drainage in 2005, and commercial fishing was limited only by market conditions and buyer interest. Subsistence restrictions were not necessary.

SPLIT-BEAM AND DIDSON COMPARISON

The relationship between the split-beam and DIDSON counts can be used to examine historical estimates in light of the improved detection with the DIDSON. The slope of the regression line suggests that DIDSON estimates are about 20% higher than split-beam. This is similar to what has been observed at other projects doing similar comparisons (Maxwell and Gove 2004; Sandall and Pfisterer 2006, M. McEwen, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). This comparison of the DIDSON and split-beam sonar estimates was conducted during periods of moderately low and high passage. Although the range of grouped 24-h estimates obtained through bootstrapping does not cover extreme low or high passage, the values should be sufficient to estimate all but the historically low passage days without extrapolating beyond the range of the data used for this analysis. The average right bank passage from 1986 through 2004 ranges from a low of 236 to a high of 3,169 chum salmon per day. The DIDSON was well suited for conditions experienced on the Sheenjek River, and proved to be easier to operate and more accurate than the split-beam sonar.

ACKNOWLEDGMENTS

The author wishes to acknowledge the sonar field camp personnel, ADF&G technicians Susan Klock, Elizabeth Smith and Yukon River Drainage Fisheries Association technician Nick Askoar for their dedication to the project, and collecting most of the data used in this report. Thanks to Pete Cleary, Bruce McIntosh and Carl Pfisterer for logistical support. Finally, I thank Eric Volk, Toshihide Hamazaki, and Bruce McIntosh for their review and editorial comments on this manuscript. This investigation was partially funded by U.S./Canada Salmon Research Cooperative under NOAA Cooperative Agreement Award Number NA04NMF4380264.

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TABLES AND FIGURES

Table 1.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981–2005.

Year	Starting Date	Ending Date	Project Duration	Sonar Estimate	Expanded Estimate
1981	31-Aug	24-Sep	25	74,560	
1982	31-Aug	22-Sep	23	31,421	
1983	29-Aug	24-Sep	27	49,392	
1984	30-Aug	25-Sep	27	27,130	
1985 [a]	02-Sep	29-Sep	28	152,768	
1986 [a]	17-Aug	24-Sep	39	83,197 [b]	84,207
1987 [a]	25-Aug	24-Sep	31	140,086	153,267
1988	21-Aug	27-Sep	38	40,866	45,206
1989	24-Aug	25-Sep	33	79,116	99,116
1990	22-Aug	28-Sep	38	62,200	77,750
1991	09-Aug	24-Sep	47	86,496	
1992	09-Aug	20-Sep	43	78,808	
1993	08-Aug	28-Sep	52	42,922	
1994	07-Aug	28-Sep	53	150,565	
1995	10-Aug	25-Sep	47	241,855	
1996	30-Jul	24-Sep	57	246,889	
1997	09-Aug	23-Sep	46	80,423	
1998	17-Aug	30-Sep	45	33,058	
1999	10-Aug	23-Sep	45	14,229	
2000	08-Aug	12-Sep	36	18,652 [c]	30,084
2001	11-Aug	23-Sep	44	53,932	
2002	09-Aug	24-Sep	47	31,642	
2003	09-Aug	26-Sep	49	38,321 [d]	44,047
2004	08-Aug	25-Sep	49	37,878	
2005 [a]	10-Aug	24-Sep	46	438,253 [d]	561,863
1981-90	26-Aug	25-Sep	31	74,074	79,482
1991-00	08-Aug	23-Sep	47	99,390	100,533
2000-04	09-Aug	22-Sep	45	36,085	39,517

[a] Sonar-estimate is based on counts from both right and left bank sonar operations, all other years are left bank estimates only.

[b] Sonar-estimated escapement in these years was subsequently expanded to include fish passing prior to sonar operations (Barton 1995). Expansions for 1986–1988 and 1990 were based upon run timing data collected in the nearby Chandalar River. The 1989 estimate was expanded based upon aerial survey observations made in the Sheenjek River prior to sonar operations in that year.

[c] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated (Barton 2002). Expansions for 2000 were based upon average run time data from the Sheenjek River 1986–1999.

[d] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansions for 2003 and 2005 were based upon run time data from the Rampart tag recovery fish wheel.

Table 2.–Sonar-estimated passage of fall chum salmon in the Sheenjek River, 2005.

	Daily			Cumulative			
Date	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total	% of Total Passage
8/10 [a]	447	ND	447	447	ND	447	0.00
8/11 [b]	549	3,741	4,290	996	3,741	4,737	0.01
8/12	495	3,133	3,628	1,491	6,874	8,365	0.02
8/13	586	3,115	3,701	2,076	9,989	12,066	0.03
8/14	759	2,644	3,403	2,835	12,633	15,469	0.04
8/15	379	2,348	2,727	3,214	14,981	18,196	0.04
8/16	529	2,314	2,843	3,743	17,295	21,039	0.05
8/17	786	2,043	2,829	4,529	19,338	23,868	0.05
8/18	813	1,566	2,379	5,342	20,904	26,246	0.06
8/19	1,093	3,073	4,166	6,436	23,977	30,413	0.07
8/20	1,944	2,237	4,181	8,380	26,214	34,594	0.08
8/21	3,025	2,433	5,458	11,405	28,647	40,052	0.09
8/22	1,305	2,211	3,516	12,709	30,858	43,567	0.10
8/23	1,846	2,151	3,997	14,555	33,009	47,564	0.11
8/24	2,277	3,268	5,545	16,832	36,277	53,109	0.12
8/25	1,643	2,265	3,908	18,475	38,542	57,017	0.13
8/26	1,265	1,841	3,106	19,740	40,383	60,123	0.14
8/27	1,812	2,477	4,289	21,552	42,860	64,412	0.15
8/28	1,836	1,380	3,216	23,388	44,240	67,628	0.15
8/29	2,042	1,552	3,594	25,430	45,792	71,222	0.16
8/30	2,308	1,561	3,869	27,738	47,353	75,091	0.17
8/31	2,612	1,956	4,568	30,350	49,309	79,659	0.18
9/01	2,423	1,162	3,585	32,773	50,471	83,244	0.19
9/02	3,027	1,378	4,405	35,800	51,848	87,649	0.20
9/03	3,410	2,629	6,039	39,210	54,477	93,688	0.21
9/04	13,620	5,295	18,915	52,830	59,772	112,603	0.26 [c]
9/05	11,390	4,865	16,255	64,220	64,637	128,858	0.29
9/06	10,201	6,957	17,158	74,421	71,594	146,016	0.33
9/07	17,700	8,189	25,889	92,121	79,783	171,905	0.39
9/08	13,651	9,521	23,172	105,772	89,304	195,077	0.45
9/09	15,625	8,735	24,360	121,397	98,039	**219,437**	**0.50**
9/10	17,951	5,935	23,886	139,348	103,974	243,323	0.56
9/11	18,126	8,024	26,150	157,474	111,998	269,472	0.61
9/12	16,678	6,232	22,910	174,152	118,230	292,382	0.67
9/13	12,968	6,477	19,445	187,120	124,707	311,827	0.71
9/14	12,649	4,948	17,597	199,769	129,655	329,424	0.75
9/15	10,723	5,687	16,410	210,492	135,343	345,835	0.79
9/16	8,661	5,617	14,278	219,153	140,960	360,113	0.82
9/17	7,910	4,889	12,799	227,063	145,849	372,912	0.85
9/18	7,160	4,837	11,997	234,223	150,686	384,909	0.88
9/19	5,193	4,736	9,929	239,416	155,422	394,838	0.90
9/20	5,106	3,225	8,331	244,522	158,647	403,169	0.92
9/21	5,001	2,780	7,781	249,523	161,427	410,950	0.94
9/22	4,290	2,507	6,797	253,813	163,934	417,747	0.95
9/23	5,953	3,994	9,947	259,766	167,928	427,694	0.98
9/24	7,196	3,363	10,559	266,962	171,291	438,253	1.00
Total	266,962	171,291	438,253	266,962	171,291	438,253	

[a] Right bank operational, no data for left bank.

[b] Both right and left banks operational.

[c] Single boxed area identifies central half of the run, and the bold box identifies median day of passage.

Table 3.–Number of minutes by bank that were either expanded or interpolated to calculate the hourly passage estimate, 2005.

Date	Right Bank	Left Bank	Total
8/10	660		660
8/11	171	759	930
8/12	10		10
8/13	66	31	97
8/14		18	18
8/15	40		40
8/16			
8/17			
8/18	10	5	15
8/19	3		3
8/20	8		8
8/21			
8/22		232	232
8/23	11		11
8/24			
8/25		22	22
8/26			
8/27			
8/28	60	64	124
8/29			
8/30			
8/31			
9/1			
9/2		14	14
9/3			
9/4			
9/5			
9/6			
9/7			
9/8	6		6
9/9			
9/10	39		39
9/11	80		80
9/12			
9/13			
9/14			
9/15		8	8
9/16			
9/17			
9/18			
9/19	149		149
9/20			
9/21			
9/22			
9/23			
9/24			
Total	1,313	1,153	2,466

Table 4.–Sheenjek River test fishing (beach seine) results, 2005.

	Number	Location	Chum Salmon Captured			Arctic
Date	of Sets	(rkm)[a]	Male	Female	Total	Grayling
8/19	2	18	0	0	0	0
8/21	4	18	2	3	5	7
8/23	2	10	0	0	0	0
8/27	2	10	6	2	8	0
8/29	3	10	4	0	4	0
9/01	4	10	5	4	9	0
9/03	1	10	14	13	27	0
9/04	5	10	9	6	15	0
9/05	3	10	6	0	6	0
9/07	4	10	10	9	19	0
9/11	3	10	16	13	29	0
9/15	1	10	8	15	23	0
9/18	1	10	3	4	7	0
9/19	3	10	10	10	20	0
9/21	2	10	4	5	9	0
9/23	2	10	12	10	22	0
Total	42		109 (54%)	94 (46%)	203	7

[a] Locations are river kilometer (rkm).

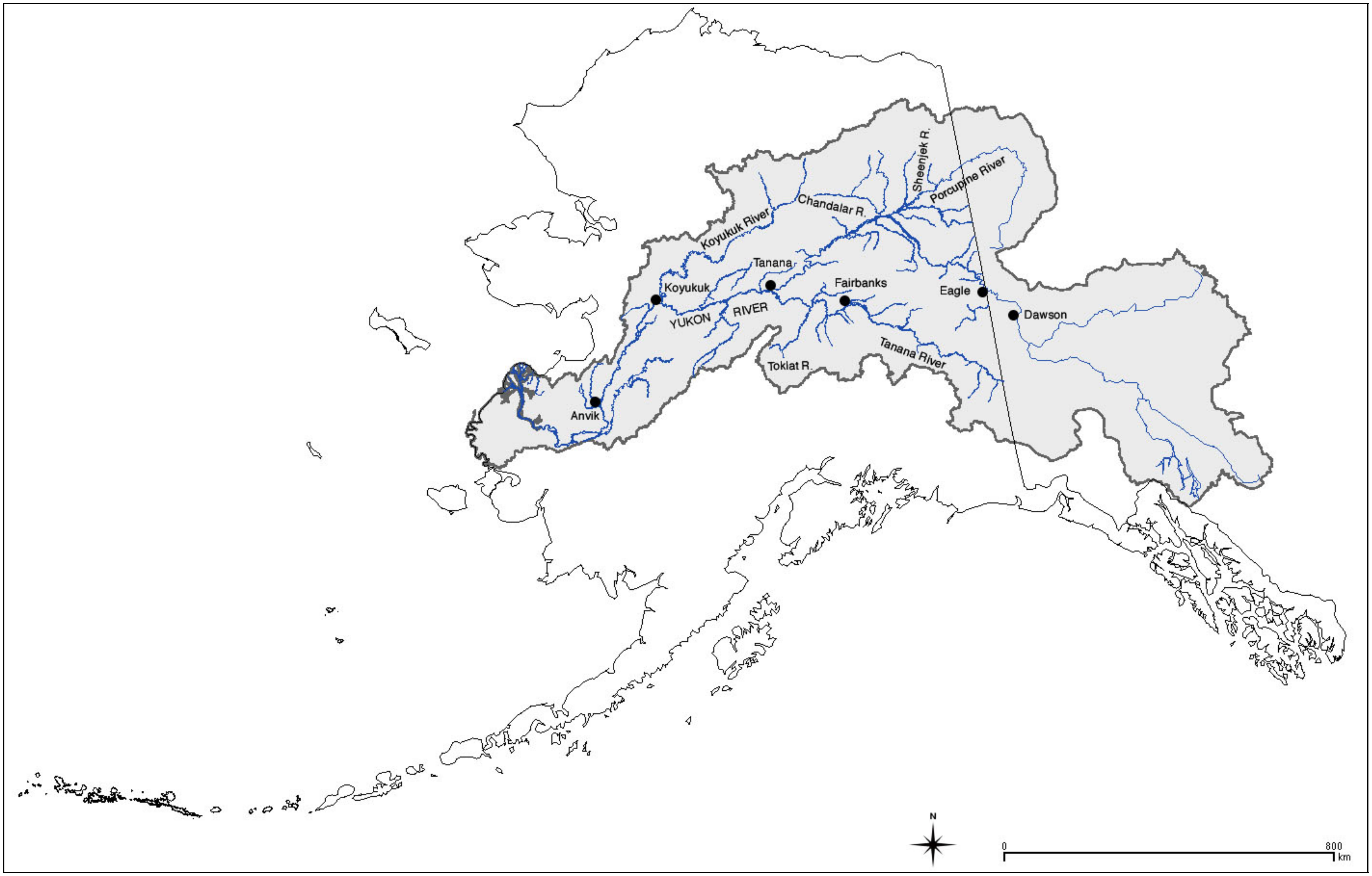

Figure 1.–The Yukon River drainage showing selected locations.

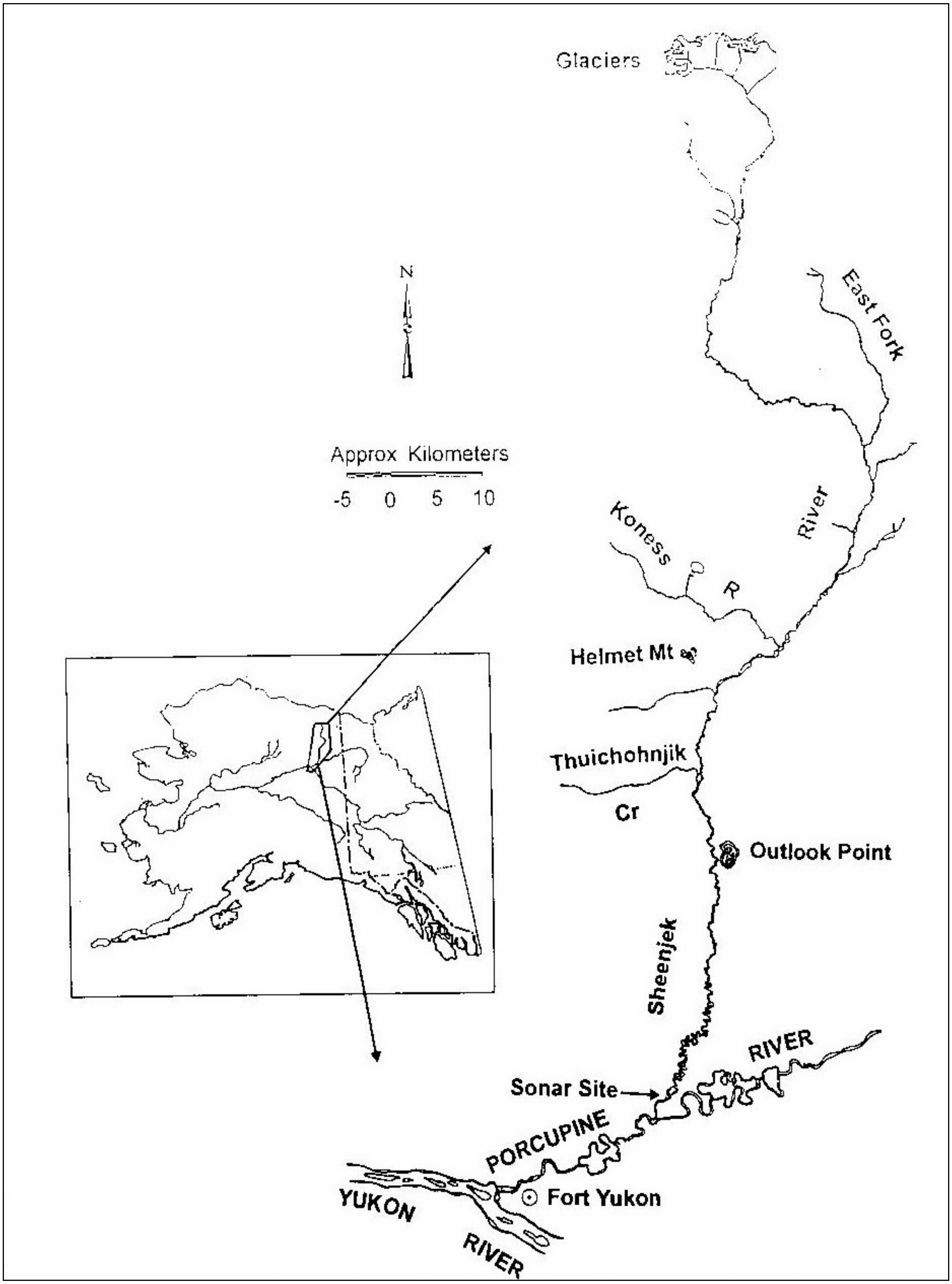

Figure 2.–The Sheenjek River drainage.

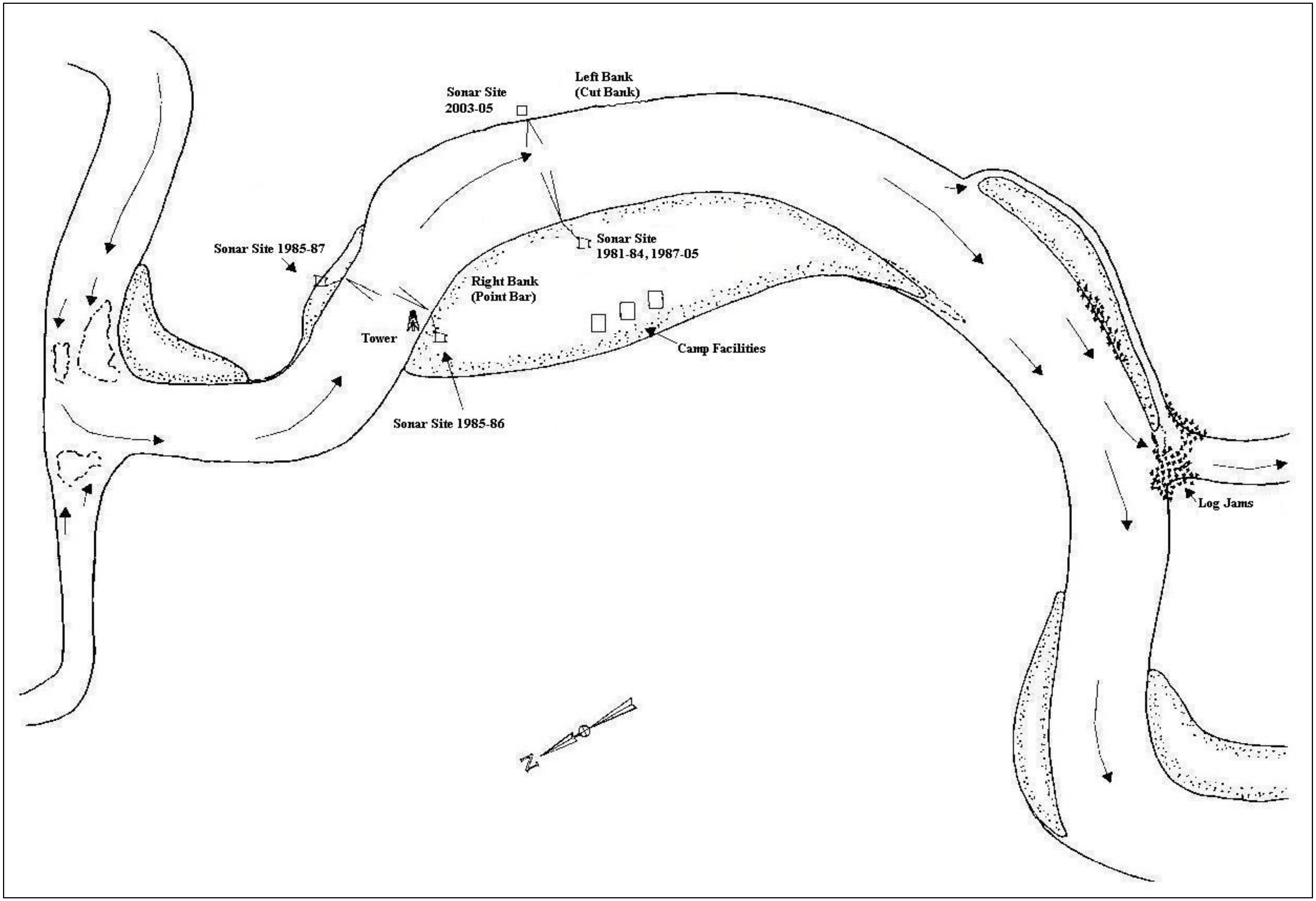

Figure 3.–The Sheenjek River sonar project site.

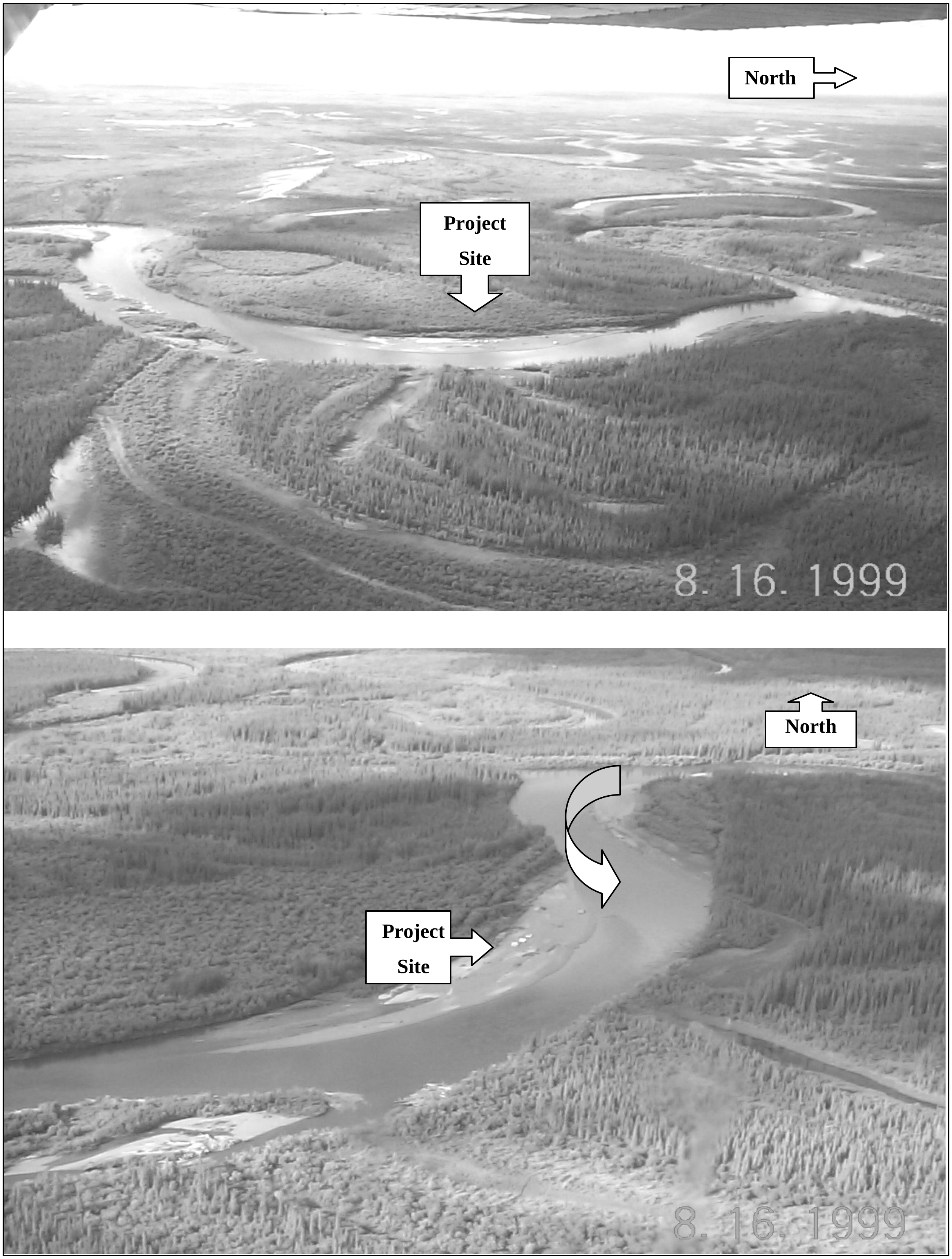

Figure 4.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

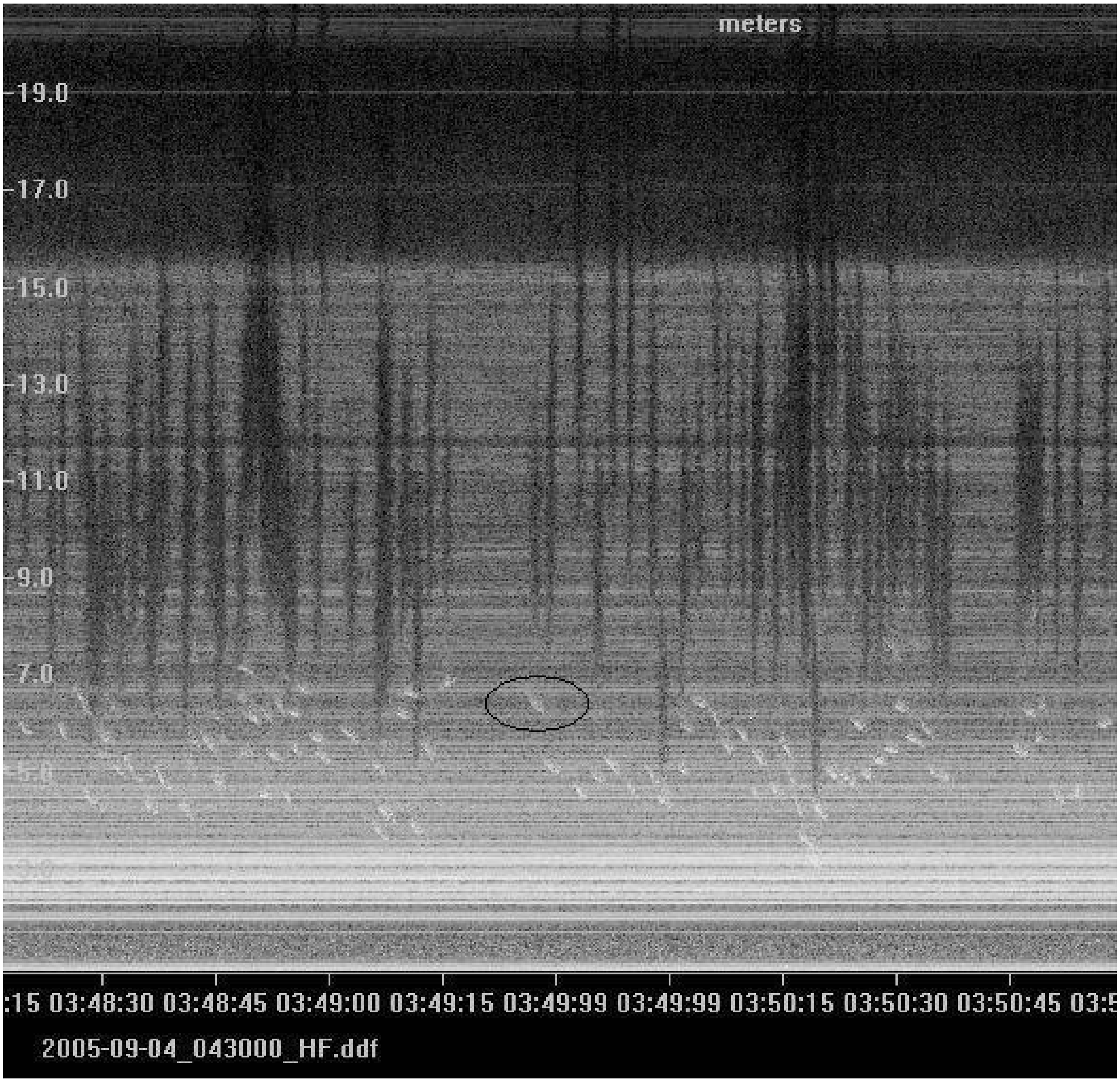

Figure 5.–Screenshot of DIDSON echogram with oval around representative fish.

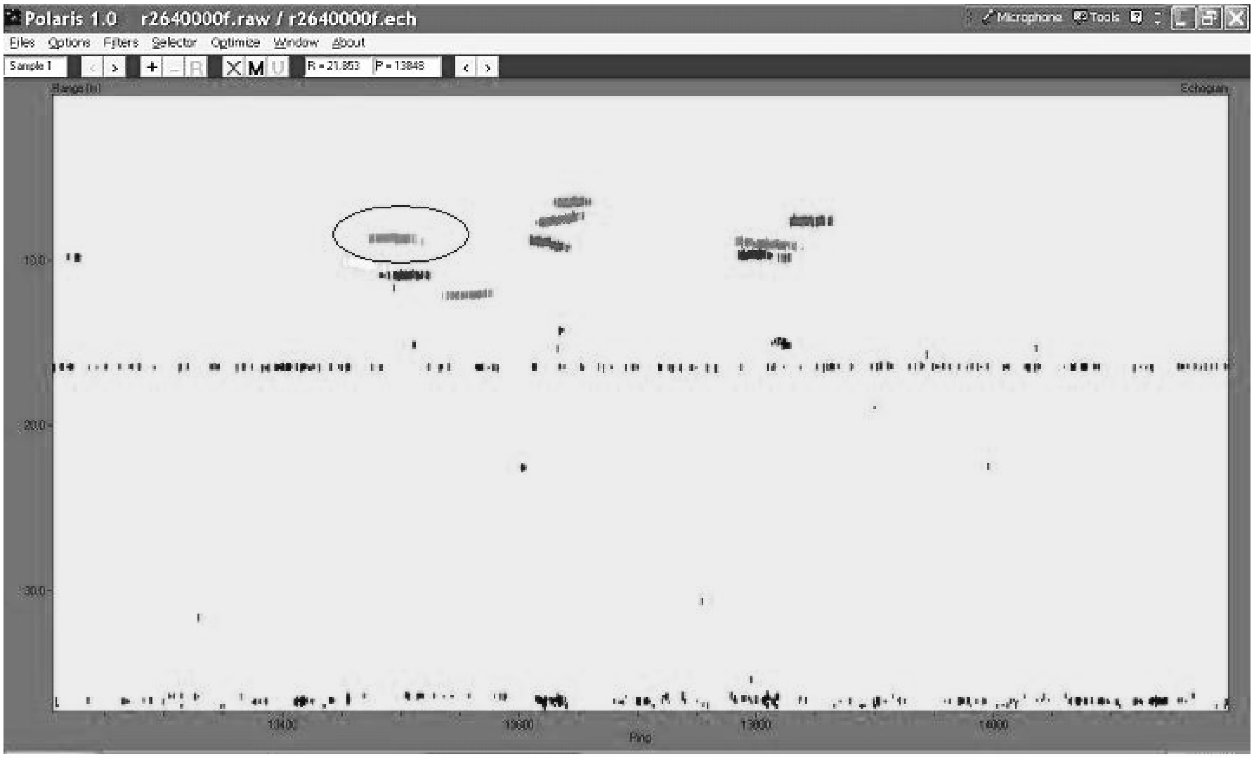

Figure 6.–Screenshot of Polaris echogram with oval around representative fish. Fish appear to be different shades of grey because the color echogram represents fish in different colors.

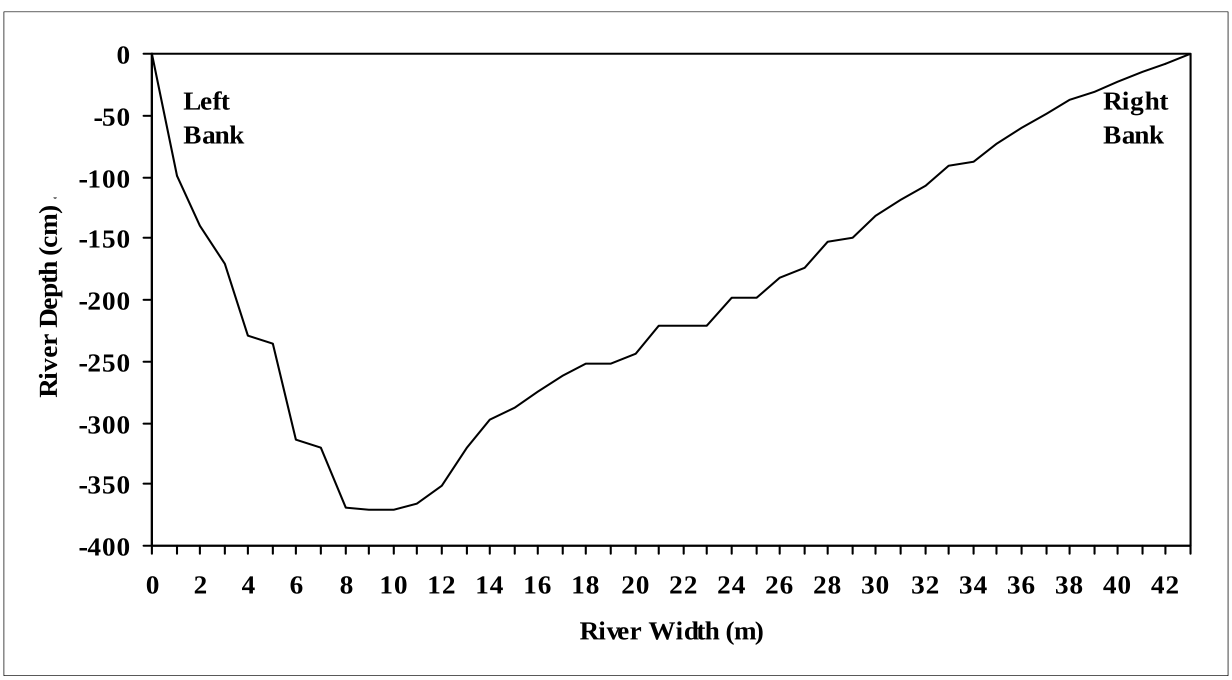

Figure 7.–Depth profile (downstream view) made August 9, 2005 at the Sheenjek River sonar site.

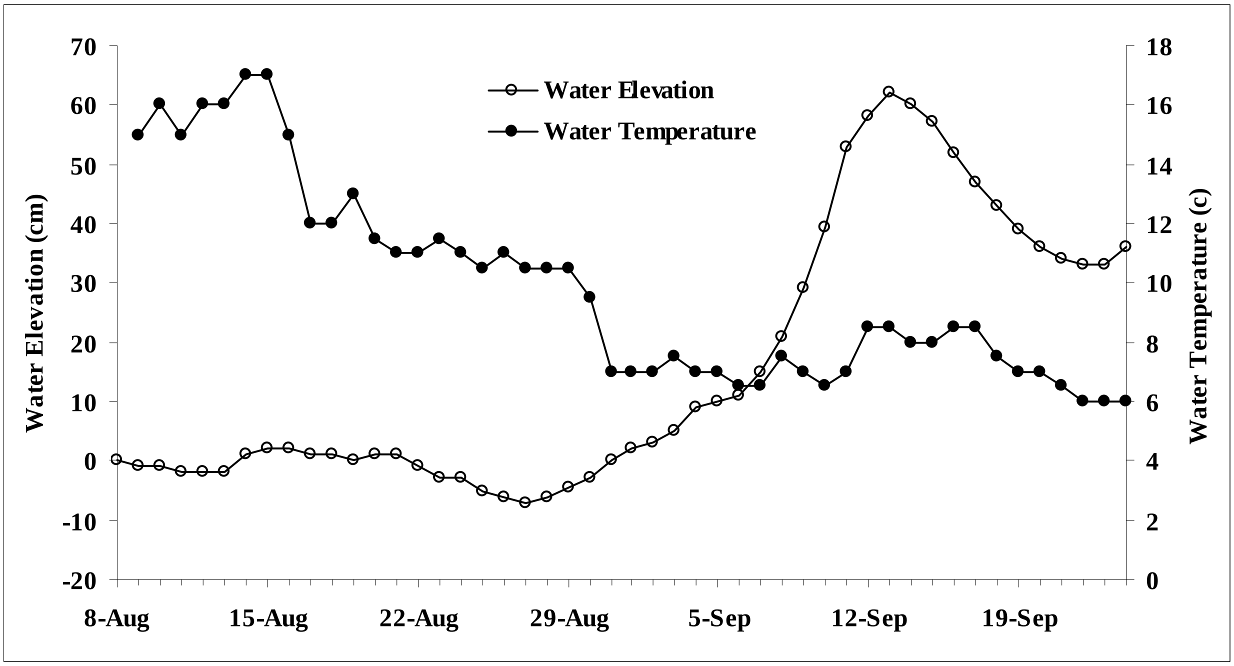

Figure 8.–Changes in daily water elevation relative to August 8, and water temperature measured at the Sheenjek River sonar project site, 2005.

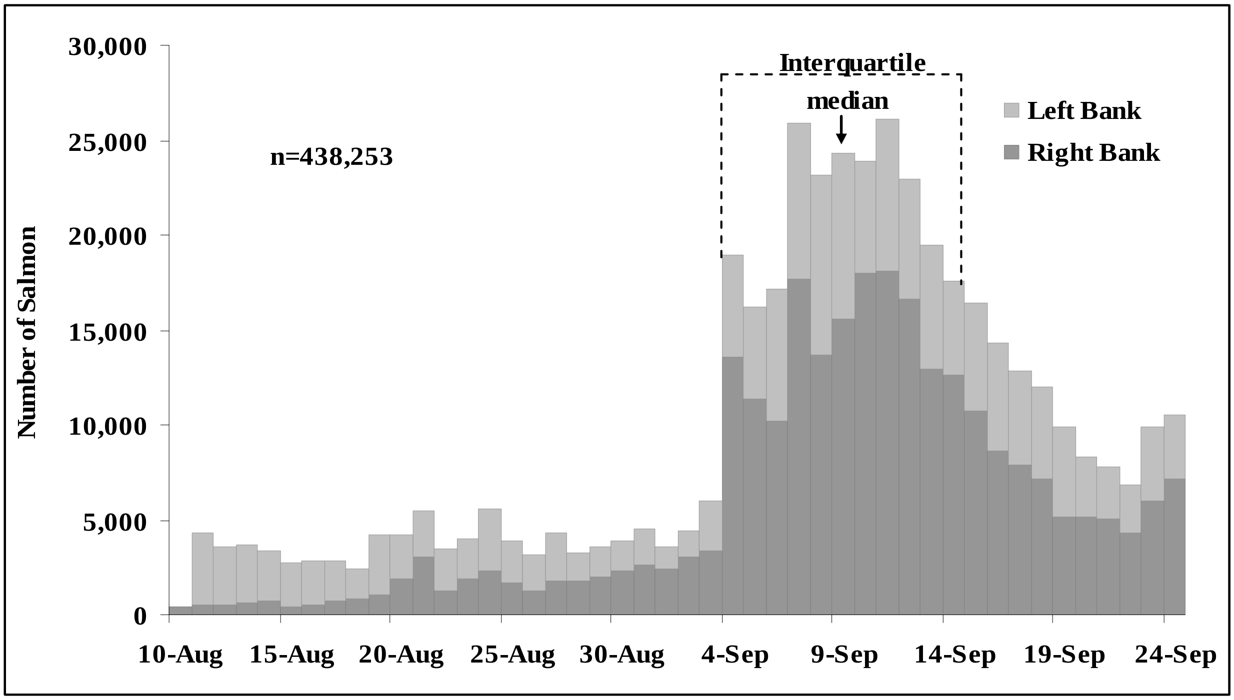

Figure 9.–Adjusted fall chum salmon sonar counts by date, Sheenjek River, 2005.

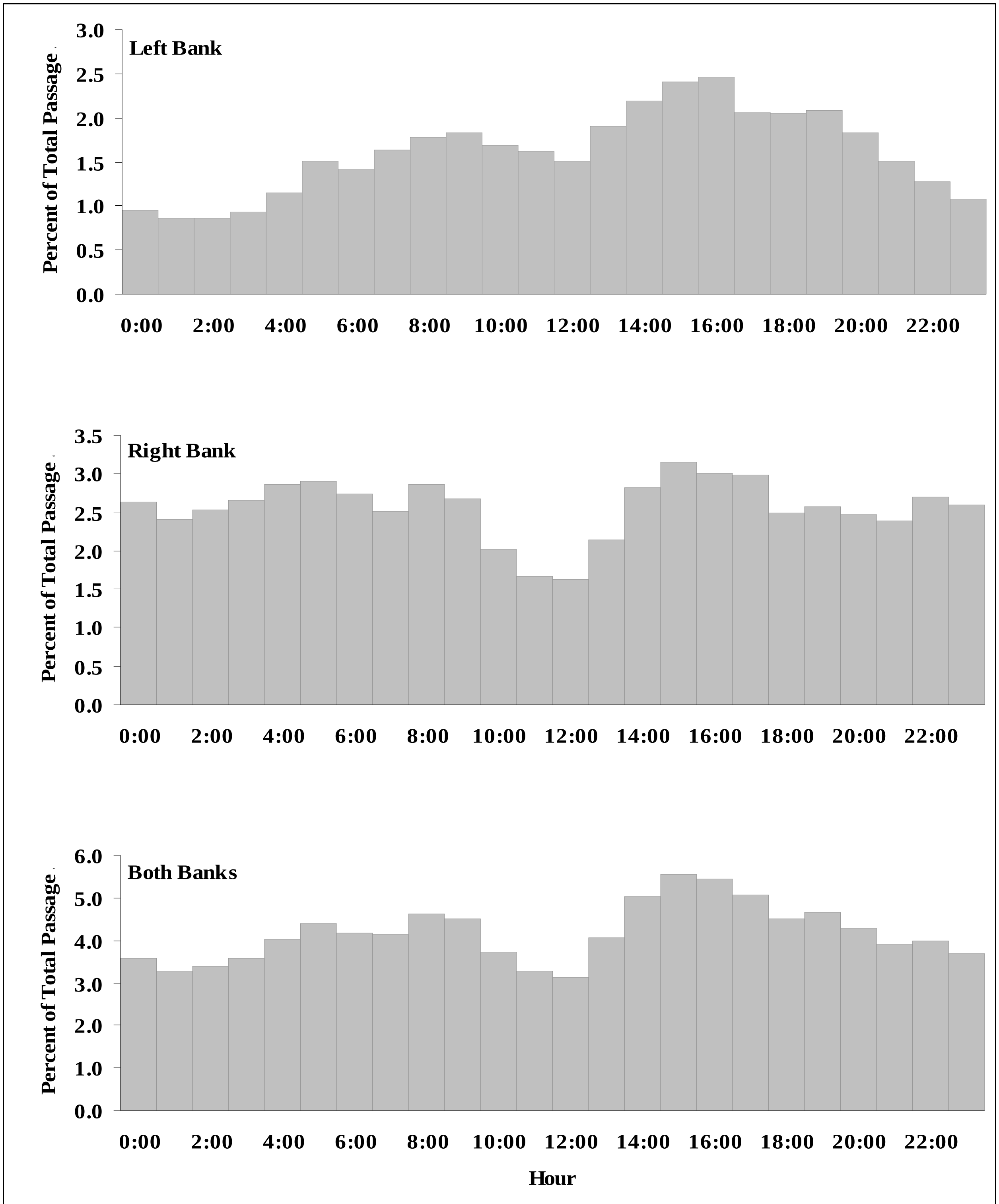

Figure 10.–Diel fall chum salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Sheenjek River, from August 11 through September 24, 2005.

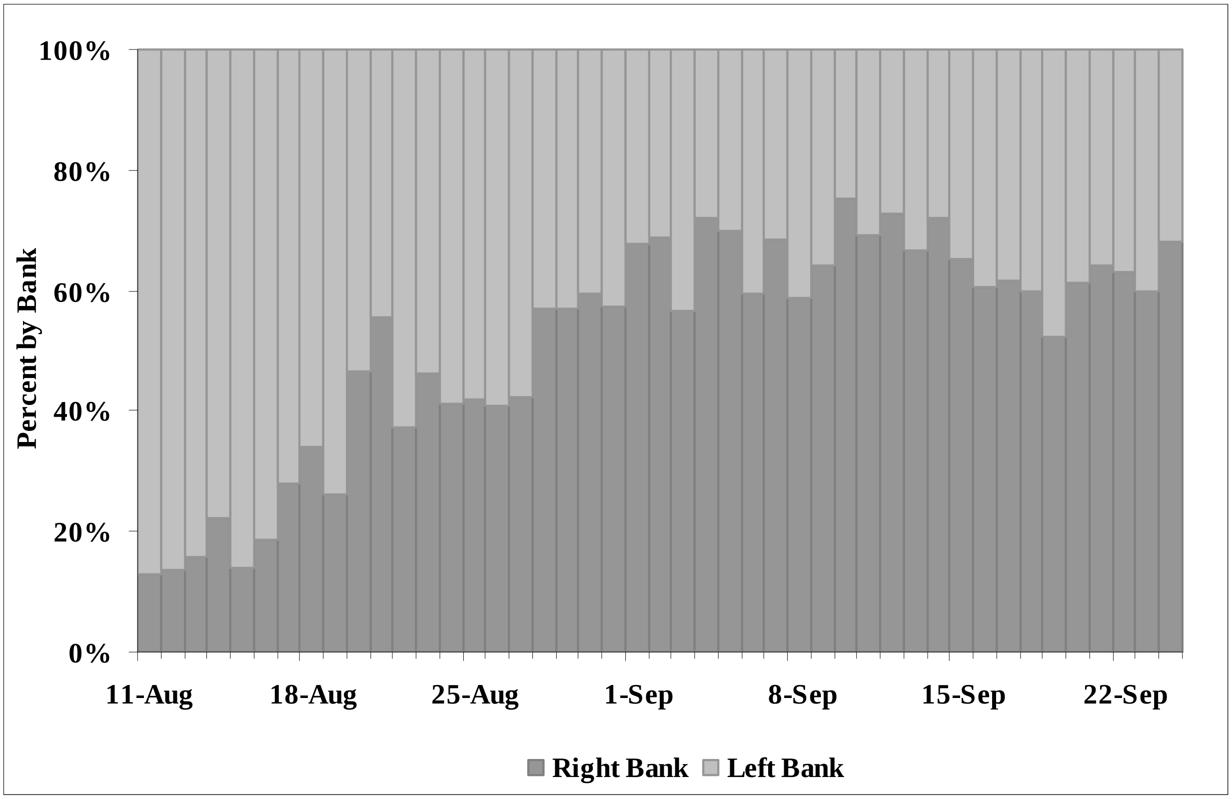

Figure 11.–Percentage of fish by bank at Sheenjek River sonar site, August 11 through September 24, 2005.

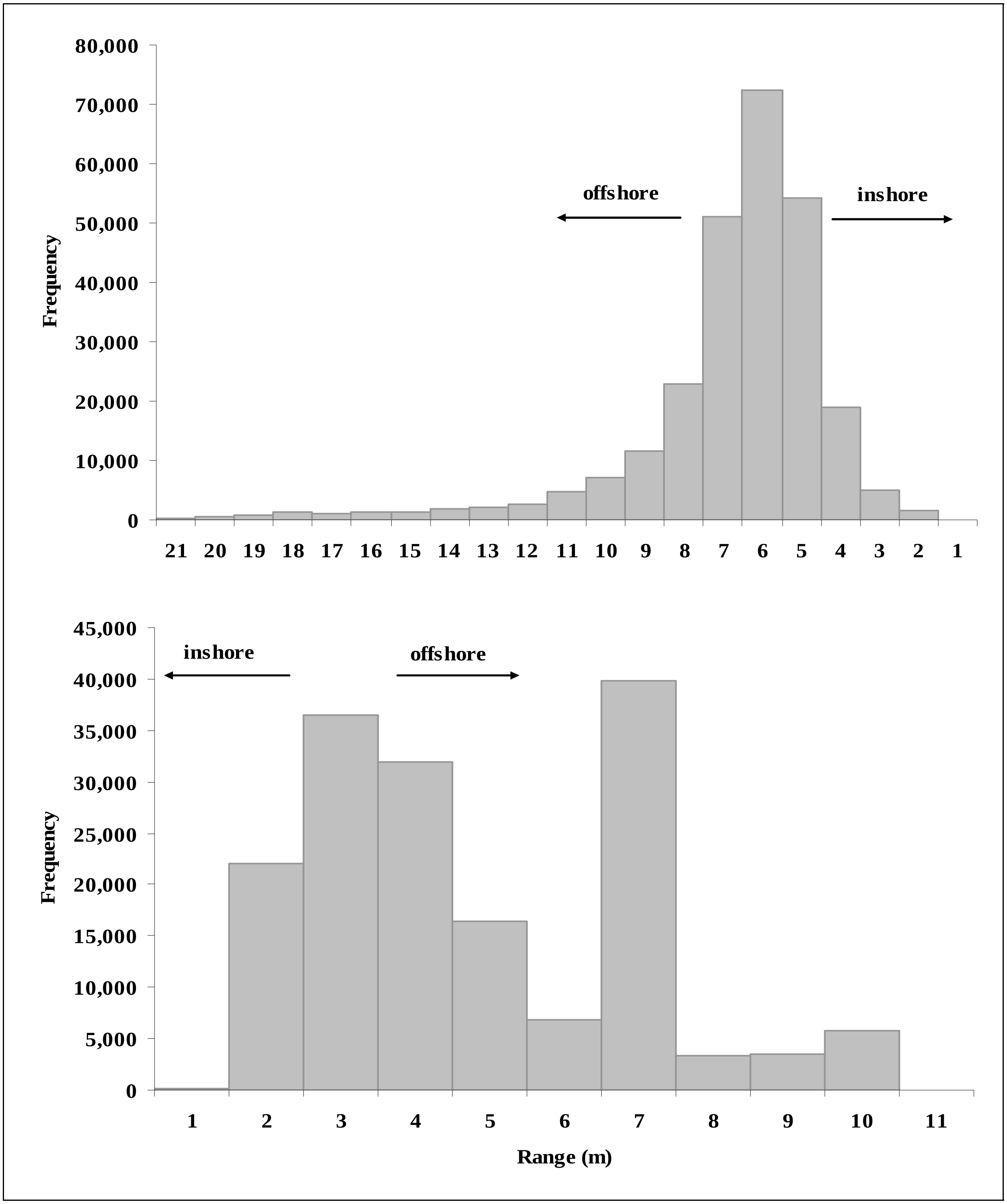

Figure 12.–Right bank (above) and left bank (below) horizontal distribution of upstream fall chum salmon passage in the Sheenjek River, 2005.

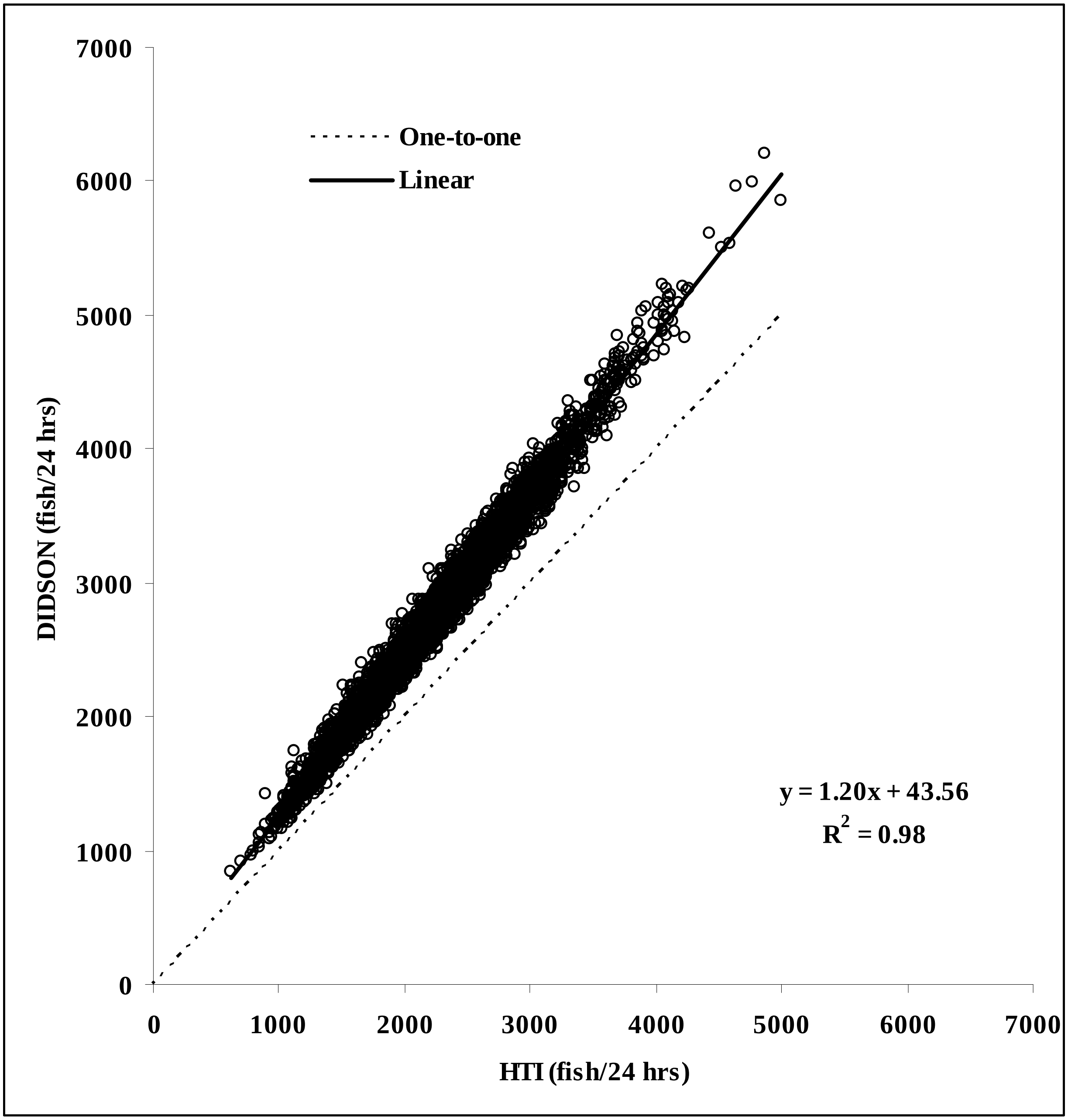

Figure 13.–Bootstrap comparison of DIDSON and HTI split-beam sonar chum salmon passage estimates in the Sheenjek River, August 18 through September 5, 2005.

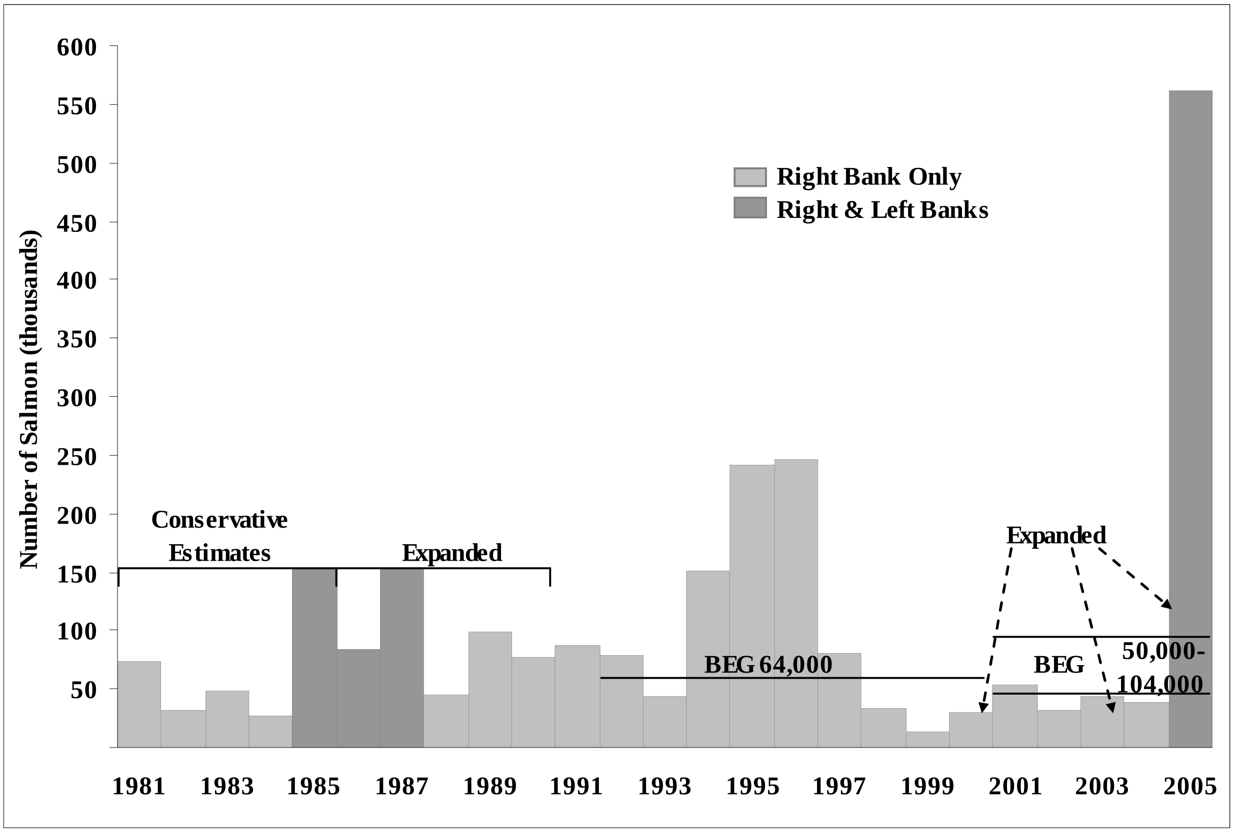

Figure 14.–Sonar-estimated escapement and BEG (horizontal lines) of fall chum salmon in the Sheenjek River, 1981–2005.

APPENDIX A. UTILIZATION OF YUKON RIVER FALL CHUM SALMON

Appendix A1.–Alaskan and Canadian total utilization of Yukon River fall chum salmon, 1970–2005.

Year	Canada [a]	Alaska [b, c]	Total
1970	3,711	265,096	268,807
1971	16,911	246,756	263,667
1972	7,532	188,178	195,710
1973	10,135	285,760	295,895
1974	11,646	383,552	395,198
1975	20,600	361,600	382,200
1976	5,200	228,717	233,917
1977	12,479	340,757	353,236
1978	9,566	331,250	340,816
1979	22,084	593,293	615,377
1980	22,218	466,087	488,305
1981	22,281	654,976	677,257
1982	16,091	357,084	373,175
1983	29,490	495,526	525,016
1984	29,267	383,055	412,322
1985	41,265	474,216	515,481
1986	14,543	303,485	318,028
1987	44,480	361,663 [d]	406,143
1988	33,565	319,677	353,242
1989	23,020	518,157	541,177
1990	33,622	316,478	350,100
1991	35,418	403,678	439,096
1992	20,815	128,031 [e]	148,846
1993	14,090	76,925 [d]	91,015
1994	38,008	131,217	169,225
1995	45,600	415,547	461,147
1996	24,354	236,569	260,923
1997	15,580	154,479 [e]	170,059
1998	7,901	62,869 [d]	70,770
1999	19,506	110,369	129,875
2000	9,236	19,307 [d]	28,543
2001	9,512	35,154 [d]	44,666
2002	8,018	19,393 [d]	27,411
2003	11,355	68,174	79,529
2004	9,750	66,165	75,915
2005 [f]	18,324	269,327	287,651
Average			
1970-04	19,921	279,794	299,715
1995-04	16,081	118,803	134,884
2000-04	9,574	41,639	51,213

Source: JTC 2006.

[a] Catch in number of salmon. Includes commercial, Aboriginal, domestic and sport catches combined.

[b] Catch in number of salmon. Includes estimated number of salmon harvested for commercial production of salmon roe.

[c] Commercial, subsistence, personal-use and ADF&G test fish catches combined.

[d] Commercial fishery did not operate in Alaskan portion of drainage.

[e] Commercial fishery operated only in District 6 (Tanana River).

[f] Data are preliminary.

APPENDIX B. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climate and hydrologic observations at the Sheenjek River project site, 2005.

Date	Time	Precipitation (code)[a]	Cloud Cover (code)[b]	Wind: Direction and velocity (mph)	Temperature (C°): Water Surface	Temperature (C°): Air Minimum	Temperature (C°): Air Maximum	Water Level (cm): ± 24 h Change	Water Level (cm): Relative to Zero Datum	Water Color (code)[c]	Remarks
08-Aug	1800	A	C	ND	ND	ND	ND	zero datum	0.0	A	Installed water stream gauge.
09-Aug	1800	A	C	S 7	15.0	ND	ND	-1.0	-1.0	A	Smoke & haze, hot & sunny all day.
10-Aug	1900	A	F	SW 2	16.0	ND	31	0.0	-1.0	A	Installed weather wizard. Smoke & haze.
11-Aug	1900	A	F	SW 7	15.0	ND	31	-1.0	-2.0	A	Smoke & haze, hot & sunny all day.
12-Aug	1800	A	F	SW 1	16.0	13	29	0.0	-2.0	A	Smoke & haze, hot & sunny all day.
13-Aug	1800	A	F	NNE 2	16.0	12	28	0.0	-2.0	A	Smoke & haze, hot & sunny all day.
14-Aug	1800	A	F	NE 11	17.0	19	24	3.0	1.0	A	Smoke, windy, sunny; wind max 19 @ 1510
15-Aug	1800	A	F	NE 5	17.0	4	26	1.0	2.0	A	Smoke, slight wind.sunny
16-Aug	1900	A	F	S 2	15.0	4	26	0.0	2.0	A	Smoke & sunny all day.
17-Aug	1800	A	F	NE 16	12.0	7	24	-1.0	1.0	A	Smoke, cool wind, heavy smoke 1600.
18-Aug	1900	A	F	NNE 1	12.0	2	16	0.0	1.0	A	Smoke, cool wind.
19-Aug	1800	A	F	SSW 11	13.0	-1	10	-1.0	0.0	A	Smoke, sunny.
20-Aug	1800	A	F	SW 5	11.5	1	20	1.0	1.0	A	Very smoky, no sun except red ball in sky.
21-Aug	1800	A	F	NW 1	11.0	7	22	0.0	1.0	A	Light smoke; can see sun & puffy clouds.
22-Aug	1800	A	F	SSW 1	11.0	5	22	-2.0	-1.0	A	Very light smoke, partly cloudy.
23-Aug	1800	A	B	0	11.5	5	23	-2.0	-3.0	A	Light smoke in am, brief sunny breaks in pm.
24-Aug	1800	A	B	SSW 8	11.0	7	23	0.0	-3.0	A	Mostly cloudy, a few raindrops at 13:30.
25-Aug	1800	A	B	SW 7	10.5	4	21	-2.0	-5.0	A	Cloudy & cool.
26-Aug	1800	A	B	NNW 3	11.0	0	23	-1.0	-6.0	A	Sunny from 1000-1500, otherwise overcast.
27-Aug	1800	B	B	N 5	10.5	6	19	-1.0	-7.0	A	Rain at night, cloudy day, smoky early morn.
28-Aug	1800	A	B	ESE 5	10.5	-1	23	1.0	-6.0	A	Cool, no smoke, cloudy.
29-Aug	1800	A	B	NNW 1	10.5	5	26	1.5	-4.5	A	Nice day, little smoke.
30-Aug	1800	A	F	NW 1	9.5	10	18	1.5	-3.0	A	Very smoky, w.wizard died in am.
31-Aug	1800	B	O	NE 6	7.0	2	13	3.0	0.0	A	Very cold, rainy all day, temp. still dropping.
01-Sep	1800	E	O	SW 4	7.0	1	4	2.0	2.0	A	Chilly, overcast all day, rain/snow overnight.
02-Sep	1800	A	S	SSW 3	7.0	-1	16	1.0	3.0	A	Cool, no smoke, sunny day.
03-Sep	1800	A	S	W 2	7.5	2	22	2.0	5.0	A	Overcast am, mostly sunny pm--nice day!!
04-Sep	1800	B	O	0	7.0	5	14	4.0	9.0	A	Rain off and on all day, cool, w.wizard died.
05-Sep	1800	B	O	NE 5	7.0	7	11	1.0	10.0	A	Rain off and on all day, bit cool, overcast.
06-Sep	1800	A/B	O	N 10	6.5	4	17	1.0	11.0	A	Rained a little during night.
07-Sep	1800	A/B	O	SW 2	6.5	5	13	4.0	15.0	A	Rained during the night.
08-Sep	1800	B/A	C	SSW 6	7.5	8	19	6.0	21.0	A	Rained during the night.
09-Sep	1800	A	O	NNE 2	7.0	-3	15	8.0	29.0	A	Clear morning, cloudy afternoon/evening.
10-Sep	1730	B/A	B	SW 6	6.5	8	16	10.5	39.5	A	Rained a little during night.
11-Sep	1800	A	B	NNE 5	7.0	3	22	13.5	53.0	A	Water gauge moved, was 94cm now 50cm.
12-Sep	1800	B	O	NNE 3	8.5	7	15	5.0	58.0	B	Morning sun, then cloudy day with showers.
13-Sep	1800	A	S	SW 8	8.5	7	18	4.0	62.0	B	Gorgeous partly cloudy fall day.
14-Sep	1800	B	O	SW 4	8.0	2	15	-2.0	60.0	B	Morning drizzle, dry cloudy windy cool day.

-continued-

Appendix B1.–Page 2 of 2.

				Wind	Temperature (C°)			Water Level (cm)			
						Air					
Date	Time	Precipitation (code)[a]	Cloud Cover (code)[b]	Direction and velocity (mph)	Water Surface	Minimum	Maximum	± 24 h Change	Relative to Zero Datum	Water Color (code)[c]	Remarks
15-Sep	1800	A	S	N 7	8.0	5	18	-3.0	57.0	B	Mostly sunny, gorgeous day; w. wizard died.
16-Sep	1800	A	S	NNE 4	8.5	6	18	-5.0	52.0	B	Morning drizzle, gorgeous partly cloudy day.
17-Sep	1800	A	B	N 8	8.5	4	19	-5.0	47.0	A	Gorgeous sunny day, cloudy after 1800.
18-Sep	1800	B	B	NNE 12	7.5	4	14	-4.0	43.0	A	Mostly cloudy, some drizzle, cold wind.
19-Sep	1800	A	B	N 5	7.0	3	12	-4.0	39.0	A	Mostly cloudy, sunny spurts throughout day.
20-Sep	1800	B	O	N 4	7.0	-2	12	-3.0	36.0	A	Overcast, sporadic drizzle, cool, little wind.
21-Sep	1800	B	B	SW 1	6.5	2	17	-2.0	34.0	A	Overcast most of day, sun came out ~ 1600.
22-Sep	1800	B	B	NE 2	6.0	-3	12	-1.0	33.0	A	Rainy morning, afternoon cloudy, cool.
23-Sep	1800	B	S	SW 7	6.0	4	14	0.0	33.0	A	Rain early am, overcast late am & early pm.
24-Sep	1800	C	O	NW 2	6.0	-1	13	3.0	36.0	A	Steady rain throughout day until ~16:00.
	Average				9.8	4	19				

[a] Precipitation code for the preceding 24-hr period: A = None; B = Intermittent rain; C = Continuous rain; D = snow and rain mixed; E = light snowfall; F = Continuous snowfall; G = Thunderstorm w/ or w/o precipitation.

[b] Cloud cover code: C = Ceiling and visibility unlimited (CAVU); S = Scattered (<60%); B = Broken (60-90%); O = Overcast (100%); F = Fog or thick haze or smoke.

[c] Water color code: A = Clear; B = Slightly murky or glacial; C = Moderately murky or glacial; D = Heavily murky or glacial; E = Brown, tannic acid stain.

APPENDIX C. AGE COMPOSITION ESTIMATES

Appendix C1.–Age composition estimates of Sheenjek River fall chum salmon, 1974–2005.

Year[a]	Sample (readable)	Age 3	Age 4	Age 5	Age 6	Estimated Escapement
1974[b]	136	0.669	0.301	0.029	0.000	89,966
1975[b]	197	0.036	0.949	0.015	0.000	173,371
1976[b]	118	0.017	0.441	0.542	0.000	26,354
1977[b]	178	0.112	0.725	0.163	0.000	45,544
1978[b]	190	0.079	0.821	0.100	0.000	32,449
1979	ND	ND	ND	ND	ND	91,372
1980	ND	ND	ND	ND	ND	28,933
1981[c]	340	0.029	0.850	0.118	0.003	74,560
1982[c]	109	0.030	0.470	0.490	0.010	31,421
1983[c]	108	0.065	0.870	0.065	0.000	49,392
1984[d]	297	0.101	0.805	0.094	0.000	27,130
1985[d]	508	0.012	0.927	0.061	0.000	152,768
1986[d]	442	0.081	0.412	0.500	0.007	84,207
1987[d]	431	0.021	0.898	0.072	0.009	153,267
1988[d,e]	120	0.025	0.683	0.292	0.000	45,206
1989[d,e]	154	0.052	0.766	0.169	0.013	99,116
1990[d]	143	0.028	0.706	0.252	0.014	77,750
1991[d]	147	0.000	0.592	0.395	0.014	86,496
1992[d]	134	0.000	0.179	0.806	0.015	78,808
1993[d,e]	192	0.005	0.640	0.339	0.016	42,922
1994[d]	173	0.012	0.561	0.405	0.023	153,000
1995[d]	166	0.012	0.542	0.386	0.060	235,000
1996[d]	191	0.016	0.330	0.618	0.037	248,000
1997	ND	ND	ND	ND	ND	80,423
1998[d]	3	ND	ND	ND	ND	33,058
1999	ND	ND	ND	ND	ND	14,229
2000	ND	ND	ND	ND	ND	30,084
2001[f]	71	0.000	0.352	0.648	0.000	53,932
2002[g]	31	0.000	0.613	0.387	0.000	31,642
2003[d]	84	0.012	0.821	0.155	0.012	44,047
2004[d]	104	0.115	0.615	0.250	0.019	37,878
2005[d]	194	0.000	0.923	0.067	0.010	561,863
Avg 1974-04		0.061	0.635	0.294	0.010	79,107
Avg 1995-04		0.026	0.546	0.407	0.021	80,829
Even Years		0.090	0.534	0.367	0.010	65,993
Odd years		0.030	0.744	0.215	0.011	93,096

[a] Age determination from scales for years 1974–1985; and from vertebrae 1986–2005.
[b] Carcass samples from spawning grounds.
[c] Escapement samples taken with 5-7/8 inch gillnets at rkm 10.
[d] Escapement samples taken with beach seine rkm 5–20.
[e] Escapement samples were predominantly taken late in run.
[f] 68 carcass samples and 5 beach seine samples collected between rkm 11 and 25.
[g] 30 beach seine samples collected at rkm 13 and 1 carcass collected at rkm 10.